AEROSPACE
Assuring Space Mission Success

Small Satellite Technology: Industry Update

Catherine Venturini
Project Engineer
The Aerospace Corporation

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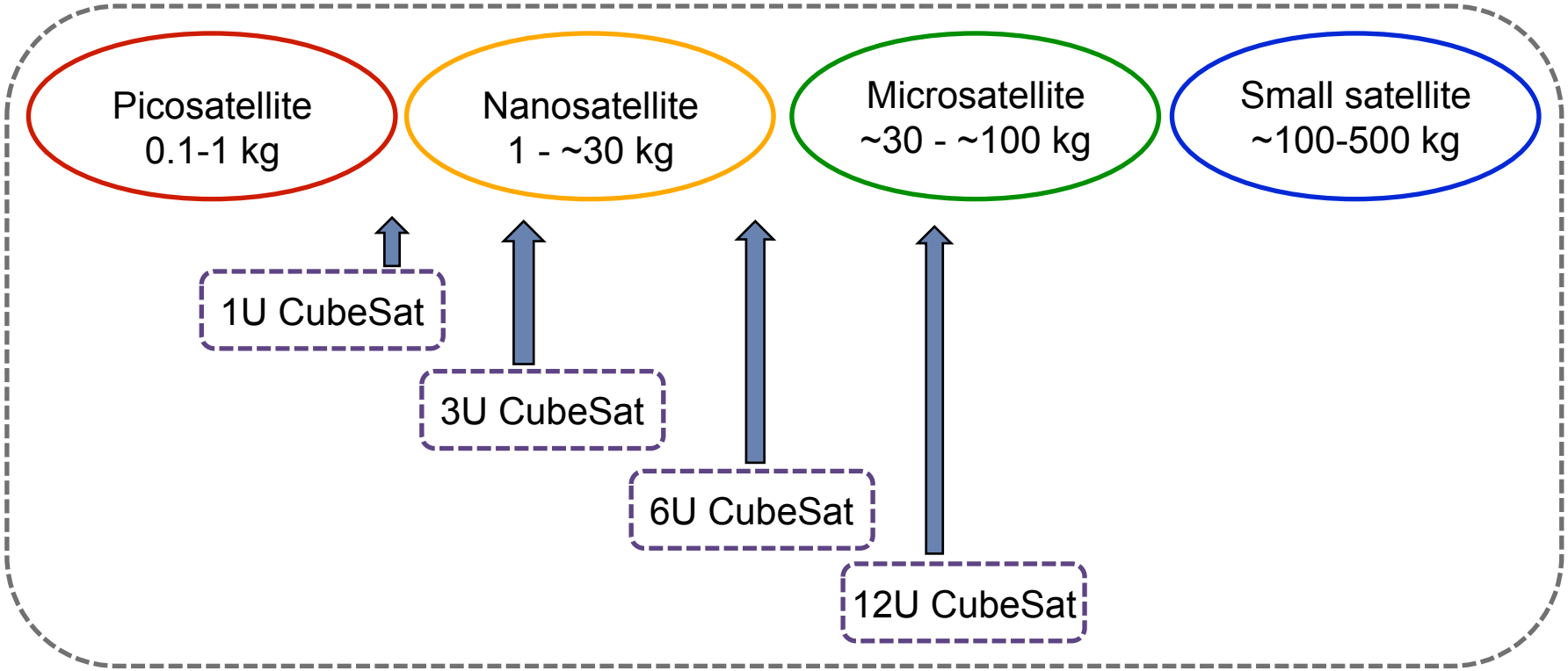
Presentation Overview

- Why Now: Technology Potential
- Definitions
- Technology Trends
  - *Imaging Payloads*
  - *Power*
  - *Attitude Determination and Control*
  - *Propulsion*
  - *Communications*
  - *Ground Systems*
  - *Launch*
- Major Industry Players
- Summary

Technology Potential for Small Satellites

- Why is there so much interest in Smallsats?
  - *Public is increasingly aware of the value of on-demand access to geospatial information*
  - *Price of entry to space and cost per kg for hardware has plummeted*
  - *Imaging payloads have become more sophisticated and lighter in weight*
  - *Proliferation of technology that can be leveraged from other sectors*
- Benefits
  - *STEM, educational aspect still strong*
  - *Increased interest in US Government*
    - Army: tactical communication, medium-resolution imagery to the warfighter via a mobile device within minutes of request
    - Navy: communications, technology development
    - NSF: Geospace and Atmospheric Research
    - NASA: earth technology and science, heliophysics, interplanetary missions, small sat technologies
  - *Small business opportunities for data products*

Small Satellite Nomenclature



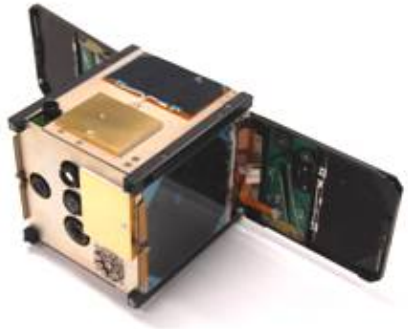
Solid ovals refer to mass categories

Dashed rectangles refer to volume categories

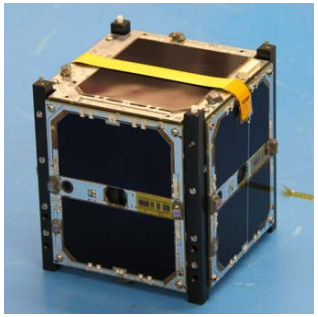
Technology Trends

Imaging Payloads

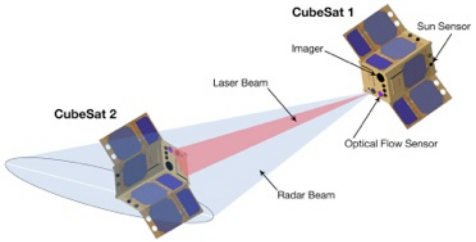
- Simple COTS sensors to advanced custom multi-band sensors, HD video capability, increasing resolution
- Aerocube 4 (launched 2012)
- M-Cubed/Cove 2 (launched 2013)
- KYSAT 2 (launched 2013)
- Planet Labs Inc. (initial launch 2013/2014)
- Skybox Imaging Inc. (initial launch 2013)
- GOMX-1 (launched 2013)
- CubeSat Proximity Operations Demonstration (CPOD) (launch 2015)
- Optical Communications and Sensor Demonstration (OCSD) (launch 2015)



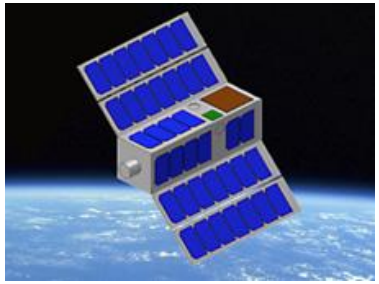
Aerocube 4



M-Cubed/COVE 2
(Reprinted with permission of C. Norton, NASA-JPL/ Caltech)



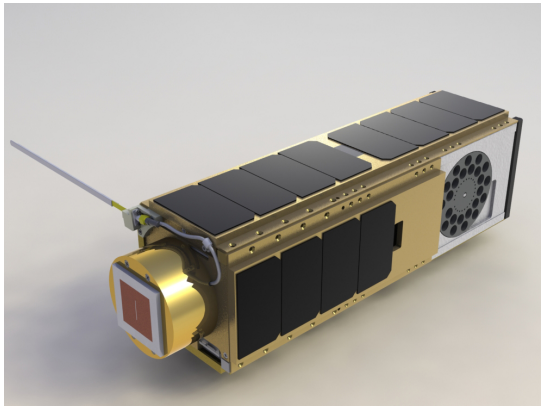
OCSD



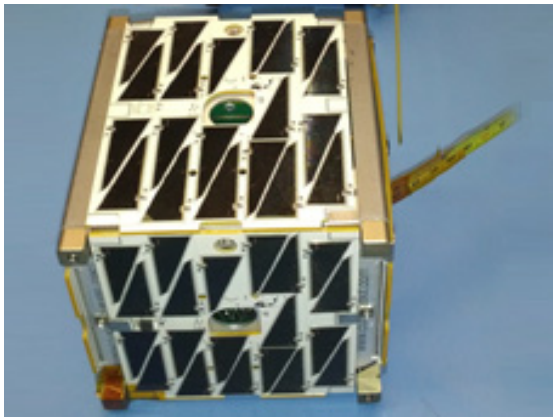
CPOD (Reprinted courtesy of NASA)

Power

- State of the Art:
  - *Early adoption of flat lithium-ion polymer battery packs*
  - *Unique in the space industry because of the higher risk tolerance of mission designers and more stringent mass/volume requirements.*
- On the Horizon: flexible solar cells which will allow for new concepts in solar panel deployment



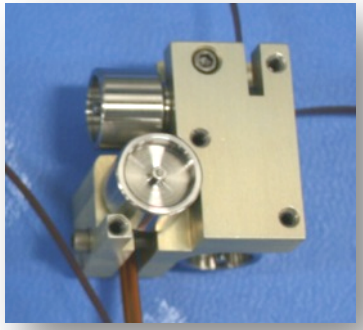
A computer-generated image of the O/OREOS nanosatellite. Launched Nov 2010. (Reprinted courtesy of NASA Ames)



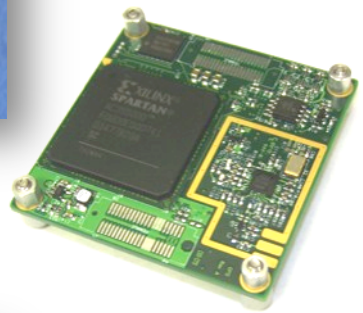
Phonesat 2.0b - high-efficiency Spectrolab Triangular Advanced Solar Cells. Launched early 2013. (Reprinted courtesy of NASA Ames)

Attitude Determination and Control

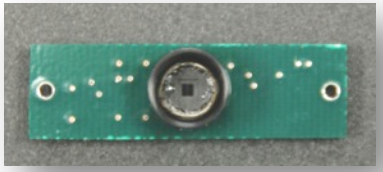
- State of the Art:
  - *Relies on miniaturizing existing technology without significant performance degradation*
  - *Miniaturization achieved through new technology such as imaging devices, materials, peripheral circuits, and algorithms*
  - *Typical Small Sat accuracy is 0.1°*
  - *Typical CubeSat accuracy is ~2° but rapidly improving*
- On the Horizon: CubeSat pointing accuracy <1°
- Technology gaps:
  - *Development of thruster technology for <100 kg satellites*
  - *Decreased development cost for ADCS software*



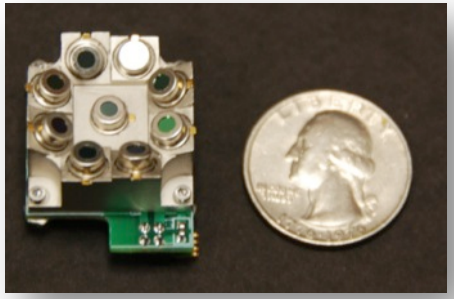
Nano-reaction wheels



GPS receiver



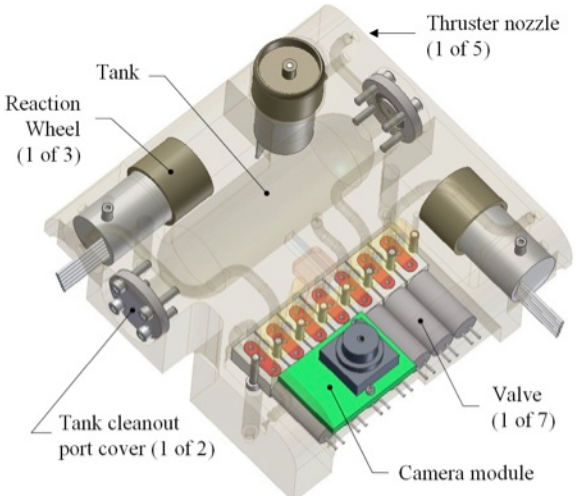
Sun sensor



Earth sensor

Propulsion

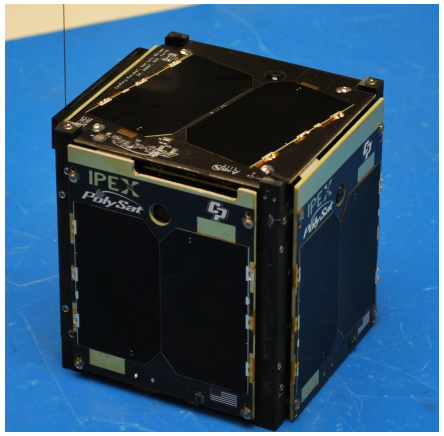
- State of the Art:
  - *Cold gas thrusters*
  - *Solid rocket motors*
  - *Pulsed plasma thrusters*
- On the Horizon: mature chemical and electric propulsion systems within 5 years



Cold gas propulsion unit. Flown in 2006.

Structures, Materials, and Mechanisms

- State of the Art:
  - *CubeSat use common standards*
  - *Micro and Minisats are "custom"*
  - *NanoSats increasingly standard; mostly custom mechanical designs for mechanisms and actuators*
- On the horizon: 3D-printed structures (additive manufacturing)

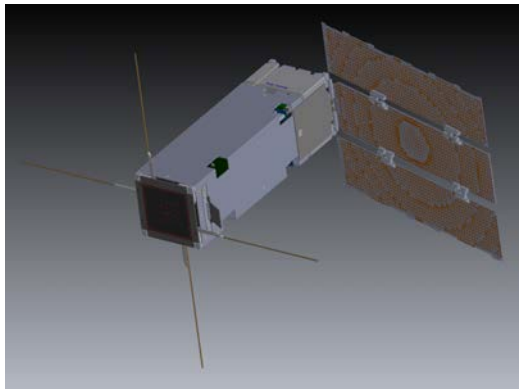


IPEX/CP-8 (Reprinted with permission of C. Norton, NASA-JPL/Caltech)

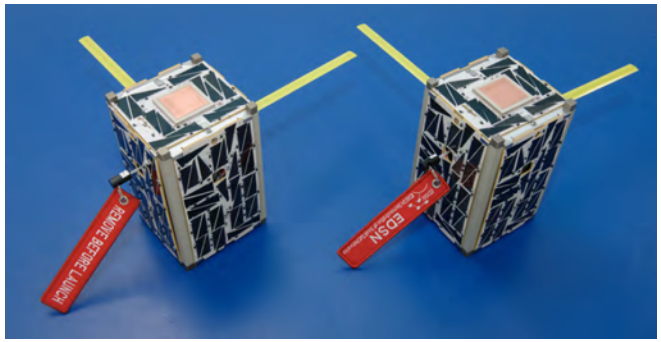
"Printed" CubeSat structure. (Reprinted courtesy of NASA Ames)

Communications

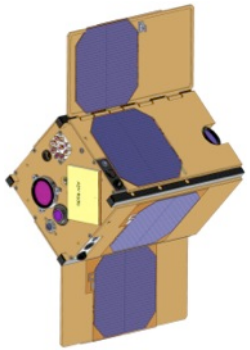
- State of the Art:
  - *Transmission using VHF, UHF, X-band, and IR/visible frequencies*
  - *Trend of increasing signal frequency and increasing data transfer speeds.*
  - *Smallsat data rates*
    - 10 Mbps in S band
    - 500 Mbps in X band
    - 1.2 Gbps in K/Ku/Ka band
  - *CubeSat data rates are lower, order of Kbps*
- On the Horizon: laser communication, deployable high-gain antennae



NASA ISARA - Ka band reflectarray. Launch late 2014. (Reprinted with permission of C. Norton, NASA-JPL/Caltech)



NASA EDSN – intersatellite communication swarm using ISM bands. Launch late 2014. (Reprinted courtesy of NASA Ames)



Aerospace Corp. OCSD – laser communication, prox. ops. Launch 2015.

Ground Systems

- State of the Art:
  - *Legacy systems*
  - *Distributed individual mission systems*
  - *Cost is driven by infrastructure and personnel*
  - *Satellite phone/data networks being tested*
  - *Primarily amateur frequency bands*
- On the Horizon:
  - *Open source software packages which enable distributed operations of small spacecraft*
  - *Commoditized networks*
- Tech gap: autonomous or highly automated operations to make swarms/constellations affordable

JPL ground station. (Reprinted with permission of C. Norton, NASA-JPL/Caltech)

Parabolic dish antenna

Launch

- State of the Art:
  - *Adapters used to launch small satellites as secondary payloads (1U-6U, ESPA class)*
  - *Rideshare cannot accommodate specialized orbits or precisely timed rendezvous*
  - *Limits advantages of small satellites such as quick acquisition time and low total cost*
- On the Horizon:
  - *Small launch vehicles*
  - *Orbital maneuvering systems*
  - *Large CubeSat deployers*
- Technology Gaps: dedicated LV's are required to fully realize rapid acquisition and mission design flexibility

CubeSats launched from the International Space Station on 4 Oct. 2012
(Reprinted courtesy of NASA)

Space X's Falcon 9 rocket 8 Dec. 2010
(Reprinted courtesy of NASA)

Small Satellite Industry Players

- Kentucky Space LLC
  - *Consortium members include Morehead State Univ (KY), associated with Prof Bob Twiggs who co-established the CubeSat technology standard while at Stanford University.*
  - *Goal: R&D, advance technology*
- GomSpace
  - *Goal: R&D, manufacturer of CubeSat components*
- Tyvak Nanosatellite Systems Inc.
  - *Close ties with Cal Poly San Luis Obispo (CA), associated with Dr. Jordi Puig-Suari who co-established the CubeSat technology standard while at CP-SLO*
  - *Goal: R&D, manufacturer of CubeSat components, launch integration, ground solutions*
- NanoRacks LLC
  - *Goal: launch services to ISS*
- Clyde Space
  - *Goal: R&D, manufacturer of CubeSat power sub-systems (EPS boards, solar panels, batteries)*
- Andrews Space/Spaceflight Inc.
  - *Goal: launch integration services, R&D, manufacturer of CubeSat components*
- ISIS (Innovative Solutions in Space)
  - *Goal: launch integration, CubeSat subsystems, ground solutions*
- Pumpkin Inc.
  - *Goal: R&D, CubeSat components, "CubeSat Kit"*

Summary

- CubeSat technology advancing at a rapid pace
- COTS technology - keeping cost low
- Future missions are becoming more complex – swarms and constellations, advanced payloads, beyond LEO orbits
- Growing industrial base especially for small businesses
- Outstanding issues in community:
  - *Access to space*
    - Rideshare opportunities are here
    - Dedicated launch on the horizon – needed for missions needing specific orbits, constellations, launch on demand
  - *Ground systems support and cost as missions become more complex, constellations*
  - *Tracking & Identification*
  - *Orbital Debris*